

**SURFACE WATER QUALITY ANALYSIS
TECHNICAL REPORT**

**SURFACE WATER MODELING OF WATER QUALITY IMPACTS ASSOCIATED
WITH COAL BED METHANE DEVELOPMENT IN THE POWDER RIVER BASIN**

Prepared in support of:

***Final Environmental Impact Statement and Proposed Plan Amendment for the Powder River
Basin Oil and Gas Project for:***

**Bureau of Land Management
Buffalo Field Office
Buffalo, Wyoming**

and

***Statewide Oil and Gas Final Environmental Impact Statement and Amendment of the Powder
River and Billings Resource Management Plans for:***

**Bureau of Land Management
Miles City Field Office
Billings Field Office
Billings, Montana**

Prepared by:

**Greystone Environmental Consultants, Inc.
Denver, Colorado**

and

**ALL Consulting
Tulsa, Oklahoma**

January 2003

TABLE OF CONTENTS

| | | |
|---------|--|------|
| 1.0 | INTRODUCTION | 1-1 |
| 2.0 | PROJECT DESCRIPTION | 2-1 |
| 2.1 | Alternatives Analyzed..... | 2-1 |
| 2.1.1 | Wyoming FEIS | 2-1 |
| 2.1.2 | Montana FEIS | 2-2 |
| 3.0 | APPROACH TO SURFACE WATER MODEL | 3-1 |
| 3.1 | Discussion of Proposed Standards | 3-1 |
| 3.2 | Evaluation Criteria | 3-3 |
| 3.2.1 | Most Restrictive Proposed Limits/Least Restrictive Proposed Limits | 3-3 |
| 3.2.2 | Ayers and Westcot Irrigation Suitability Diagram | 3-4 |
| 3.2.3 | Percent of CBM Discharge | 3-5 |
| 4.0 | DEVELOPMENT OF SURFACE WATER MODEL | 4-1 |
| 4.1 | Methodology | 4-1 |
| 4.2 | Model Input Parameters | 4-1 |
| 4.2.1 | Stream Quantity and Quality | 4-2 |
| 4.2.2 | CBM Quantity and Quality | 4-4 |
| 4.2.2.1 | CBM Wells | 4-4 |
| 4.2.3 | Water Losses | 4-6 |
| 4.3 | Assumptions | 4-7 |
| 5.0 | IMPACTS PROJECTED BY THE SURFACE WATER MODEL | 5-1 |
| 5.1 | Wyoming Streams | 5-1 |
| 5.1.1 | Belle Fourche River | 5-1 |
| 5.1.2 | Cheyenne River | 5-9 |
| 5.1.3 | Upper Powder River | 5-12 |
| 5.1.4 | Clear Creek | 5-12 |
| 5.1.5 | Crazy Woman Creek | 5-12 |
| 5.1.6 | Salt Creek | 5-12 |
| 5.2 | Wyoming/Montana Streams | 5-12 |
| 5.2.1 | Upper Tongue River | 5-12 |
| 5.2.2 | Powder River | 5-12 |
| 5.2.3 | Little Powder River | 5-12 |
| 5.3 | Montana Streams | 5-12 |
| 5.3.1 | Tongue River | 5-12 |
| 5.3.2 | Powder River | 5-12 |
| 5.3.3 | Little Powder River | 5-12 |
| 5.3.4 | Mizpah Creek | 5-12 |
| 5.3.4 | Bighorn/Little Bighorn Rivers | 5-12 |
| 5.3.5 | Rosebud Creek | 5-12 |
| 5.3.6 | Yellowstone River | 5-12 |
| 6.0 | CUMULATIVE IMPACTS TO SURFACE WATER PROJECTED BY THE MODEL | 6-12 |
| 7.0 | REFERENCES | 7-12 |

FIGURES

| | | |
|-------------|---|------|
| Figure 1-1 | Analysis Area, Powder River Basin, Wyoming and Montana..... | 1-2 |
| Figure 5-1 | Stream EC Before and After Mixing-Upper Belle Fourche River Sub-Watershed | 5-5 |
| Figure 5-2 | Stream SAR Before and After Mixing-Upper Belle Fourche River Sub-Watershed | 5-6 |
| Figure 5-3 | Irrigation Suitability Before and After Mixing – Upper Belle Fourche River Sub-Watershed | 5-7 |
| Figure 5-4 | Irrigation Suitability Before and After Mixing with Varying Proportions of CBM Discharge – Upper Belle Fourche River Sub-Watershed | 5-8 |
| Figure 5-5 | Stream EC Before and After Mixing-Antelope Creek Sub-Watershed | 5-12 |
| Figure 5-6 | Stream SAR Before and After Mixing- Antelope Creek Sub-Watershed..... | 5-12 |
| Figure 5-7 | Irrigation Suitability Before and After Mixing – Antelope Creek Sub-Watershed | 5-12 |
| Figure 5-8 | Irrigation Suitability Before and After Mixing with Varying Proportions of CBM Discharge – Antelope Creek Sub-Watershed | 5-12 |
| Figure 5-9 | Stream EC Before and After Mixing- the Upper Cheyenne River Sub-Watershed..... | 5-12 |
| Figure 5-10 | Stream SAR Before and After Mixing- the Upper Cheyenne River Sub-Watershed..... | 5-12 |
| Figure 5-12 | Irrigation Suitability Before and After Mixing with Varying Proportions of CBM Discharge – the Upper Cheyenne River Sub-Watershed | 5-12 |
| Figure 5-13 | Stream EC Before and After Mixing-Upper Powder River Sub-Watershed | 5-12 |
| Figure 5-14 | Stream SAR Before and After Mixing-Upper Powder River Sub-Watershed..... | 5-12 |
| Figure 5-15 | Irrigation Suitability Before and After Mixing – Upper Powder River Sub-Watershed ... | 5-12 |
| Figure 5-17 | Stream EC Before and After Mixing-Clear Creek Sub-Watershed | 5-12 |
| Figure 5-18 | Stream SAR Before and After Mixing- Clear Creek Sub-Watershed..... | 5-12 |
| Figure 5-19 | Irrigation Suitability Before and After Mixing – Clear Creek Sub-Watershed | 5-12 |
| Figure 5-20 | Irrigation Suitability Before and After Mixing with Varying Proportions of CBM Discharge – Clear Creek Sub-Watershed | 5-12 |
| Figure 5-21 | Stream EC Before and After Mixing-Crazy Woman Creek Sub-Watershed..... | 5-12 |
| Figure 5-22 | Stream SAR Before and After Mixing- Crazy Woman Creek Sub-Watershed..... | 5-12 |
| Figure 5-24 | Irrigation Suitability Before and After Mixing with Varying Proportions of CBM Discharge – Crazy Woman Creek Sub-Watershed | 5-12 |
| Figure 5-25 | Stream EC Before and After Mixing-Upper Tongue River Sub-Watershed | 5-12 |
| Figure 5-26 | Stream SAR Before and After Mixing-Upper Tongue River Sub-Watershed..... | 5-12 |
| Figure 5-28 | Irrigation Suitability Before and After Mixing with Varying Proportions of CBM Discharge – Upper Tongue River Sub-Watershed | 5-12 |
| Figure 5-29 | Stream EC Before and After Mixing- Middle Powder River Sub-Watershed..... | 5-12 |
| Figure 5-30 | Stream SAR Before and After Mixing- Middle Powder River Sub-Watershed | 5-12 |
| Figure 5-31 | Irrigation Suitability Before and After Mixing – Middle Powder River Sub-Watershed | 5-12 |
| Figure 5-32 | Irrigation Suitability Before and After Mixing with Varying Proportions of CBM Discharge – Middle Powder River Sub-Watershed | 5-12 |
| Figure 5-33 | Stream EC Before and After Mixing-Little Powder River Sub-Watershed..... | 5-12 |
| Figure 5-34 | Stream SAR Before and After Mixing-Little Powder River Sub-Watershed..... | 5-12 |
| Figure 5-35 | Irrigation Suitability Before and After Mixing - Little Powder River Sub-Watershed | 5-12 |
| Figure 5-37 | Stream EC Before and After Mixing-Upper Tongue River Sub-Watershed | 5-12 |
| Figure 5-38 | Stream SAR Before and After Mixing-Upper Tongue River Sub-Watershed..... | 5-12 |
| Figure 5-39 | Irrigation Suitability Before and After Mixing – Upper Tongue River Sub-Watershed | 5-12 |

| | | |
|-------------|--|------|
| Figure 5-40 | Irrigation Suitability Before and After Mixing with Varying Proportions of CBM Discharge – Upper Tongue River Sub-Watershed | 5-12 |
| Figure 5-41 | Stream EC Before and After Mixing-Lower Tongue River Sub-Watershed..... | 5-12 |
| Figure 5-42 | Stream SAR Before and After Mixing-Lower Tongue River Sub-Watershed | 5-12 |
| Figure 5-43 | Irrigation Suitability Before and After Mixing – Lower Tongue River Sub-Watershed | 5-12 |
| Figure 5-44 | Irrigation Suitability Before and After Mixing with Varying Proportions of CBM Discharge – Lower Tongue River Sub-Watershed | 5-12 |
| Figure 5-45 | Stream EC Before and After Mixing-Lower Powder River Sub-Watershed..... | 5-12 |
| Figure 5-46 | Stream SAR Before and After Mixing-Lower Powder River Sub-Watershed | 5-12 |
| Figure 5-47 | Irrigation Suitability Before and After Mixing – Lower Powder River Sub-Watershed..... | 5-12 |
| Figure 5-48 | Irrigation Suitability Before and After Mixing with Varying Proportions of CBM Discharge – Lower Powder River Sub-Watershed..... | 5-12 |
| Figure 5-49 | Stream EC Before and After Mixing- Mizpah Creek Sub-Watershed..... | 5-12 |
| Figure 5-50 | Stream SAR Before and After Mixing- Mizpah Creek Sub-Watershed | 5-12 |
| Figure 5-51 | Irrigation Suitability Before and After Mixing – Mizpah Creek Sub-Watershed..... | 5-12 |
| Figure 5-52 | Irrigation Suitability Before and After Mixing with Varying Proportions of CBM Discharge – Mizpah Creek Sub-Watershed | 5-12 |
| Figure 5-53 | Stream EC Before and After Mixing-Little Bighorn River Sub-Watershed..... | 5-12 |
| Figure 5-54 | Stream SAR Before and After Mixing- Little Bighorn River Sub-Watershed | 5-12 |
| Figure 5-55 | Irrigation Suitability Before and After Mixing – Little Bighorn River Sub-Watershed..... | 5-12 |
| Figure 5-56 | Irrigation Suitability Before and After Mixing with Varying Proportions of CBM Discharge – Little Bighorn River Sub-Watershed | 5-12 |
| Figure 5-57 | Stream EC Before and After Mixing-Lower Bighorn River Sub-Watershed | 5-12 |
| Figure 5-58 | Stream SAR Before and After Mixing-Lower Bighorn River Sub-Watershed | 5-12 |
| Figure 5-59 | Irrigation Suitability Before and After Mixing – Lower Bighorn River Sub-Watershed..... | 5-12 |
| Figure 5-60 | Irrigation Suitability Before and After Mixing with Varying Proportions of CBM Discharge – Lower Bighorn River Sub-Watershed | 5-12 |
| Figure 5-61 | Stream EC Before and After Mixing-Rosebud Creek Sub-Watershed..... | 5-12 |
| Figure 5-62 | Stream SAR Before and After Mixing- Rosebud Creek Sub-Watershed | 5-12 |
| Figure 5-63 | Irrigation Suitability Before and After Mixing – Rosebud Creek Sub-Watershed..... | 5-12 |
| Figure 5-64 | Irrigation Suitability Before and After Mixing with Varying Proportions of CBM Discharge – Rosebud Creek Sub-Watershed | 5-12 |
| Figure 5-65 | Stream EC Before and After Mixing- Rosebud Creek Sub-Watershed | 5-12 |
| Figure 5-66 | Stream SAR Before and After Mixing- Rosebud Creek Sub-Watershed | 5-12 |
| Figure 5-67 | Irrigation Suitability Before and After Mixing – Rosebud Creek Sub-Watershed..... | 5-12 |
| Figure 5-68 | Irrigation Suitability Before and After Mixing with Varying Proportions of CBM Discharge – Rosebud Creek Sub-Watershed | 5-12 |
| Figure 5-69 | Stream EC Before and After Mixing-Lower Yellowstone River Sub-Watershed..... | 5-12 |
| Figure 5-70 | Stream SAR Before and After Mixing- Lower Yellowstone River Sub-Watershed | 5-12 |
| Figure 5-71 | Irrigation Suitability Before and After Mixing – Lower Yellowstone River Sub-Watershed..... | 5-12 |
| Figure 5-72 | Irrigation Suitability Before and After Mixing with Varying Proportions of CBM Discharge – Lower Yellowstone River Sub-Watershed | 5-12 |
| Figure 5-73 | Stream EC Before and After Mixing- Lower Yellowstone River Sub-Watershed..... | 5-12 |

| | | |
|-------------|---|------|
| Figure 5-74 | Stream SAR Before and After Mixing- Lower Yellowstone River Sub-Watershed | 5-12 |
| Figure 5-75 | Irrigation Suitability Before and After Mixing – Lower Yellowstone River Sub-Watershed..... | 5-12 |
| Figure 5-76 | Irrigation Suitability Before and After Mixing with Varying Proportions of CBM Discharge – Lower Yellowstone River Sub-Watershed | 5-12 |

APPENDICES

Appendix A – Numeric Standards Proposed for the Tongue, Powder, and Little Powder River Basins, and Adopted for the Cheyenne and Belle Fourche River Basins

Appendix B – Analysis of SAR Mixing

Appendix C – Existing Stream Flow and Water Quality Parameters at Selected Gauging Stations within the PRB

Appendix D – Coal Bed Methane Parameters Used to Evaluate Potential Impacts to Surface Water Quality

Appendix E – Comparison of Surface Water Model Predictions with Actual Observed Data

TABLES

| | | |
|------------|--|------|
| Table 3-1 | Summary of Proposed Limits for Surface Water Impact Analysis | 3-4 |
| Table 4-1 | Summary of Input Parameters | 4-2 |
| Table 5-1 | Impact Analysis for Surface Water of the Upper Belle Fourche River Sub-Watershed | 5-3 |
| Table 5-2 | Surface Water Impact Analysis of the Antelope Creek Sub-Watershed | 5-11 |
| Table 5-3 | Surface Water Impact Analysis of the Upper Cheyenne River Sub-Watershed | 5-12 |
| Table 5-4 | Surface Water Impact Analysis of the Upper Powder River Sub-Watershed | 5-12 |
| Table 5-5 | Surface Water Impact Analysis of the Clear Creek Sub-Watershed | 5-12 |
| Table 5-6 | Surface Water Impact Analysis of the Crazy Woman Creek Sub-Watershed..... | 5-12 |
| Table 5-7 | Surface Water Impact Analysis of the Salt Creek Sub-Watershed..... | 5-12 |
| Table 5-8 | Surface Water Impact Analysis of the Upper Tongue River Sub-Watershed | 5-12 |
| Table 5-9 | Surface Water Impact Analysis of the Middle Powder River Sub-Watershed..... | 5-12 |
| Table 5-10 | Surface Water Impact Analysis of the Little Powder River Sub-Watershed..... | 5-12 |
| Table 5-11 | Surface Water Impact Analysis of the Upper/Lower Tongue River Sub-Watershed... | 5-12 |
| Table 5-12 | Surface Water Impact Analysis of the Middle/Lower Powder River Sub-Watershed . | 5-12 |
| Table 5-13 | Surface Water Impact Analysis of the Mizpah Creek Sub-Watershed..... | 5-12 |
| Table 5-14 | Surface Water Impact Analysis of the Little Bighorn/Bighorn River Sub-Watersheds..... | 5-12 |
| Table 5-15 | Surface Water Impact Analysis of the Rosebud Creek Sub-Watershed..... | 5-12 |
| Table 5-16 | Surface Water Impact Analysis of the Lower Yellowstone-Sunday/Lower Yellowstone Sub-Watersheds..... | 5-12 |
| Table 6-1 | Cumulative Surface Water Impact Analysis | 5-12 |